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High-speed video analysis of plasma behavior and estimation of laser absorption in internal processing of glass by femtosecond laser

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The purpose of this study is elucidation of the process mechanism in the microprocessing of glass by an ultrashort pulse laser. In order to achieve this purpose, the plasma behavior due to femtosecond laser irradiation was observed by a high-speed camera, and laser absorption by plasma was investigated. In the experiments, pulse duration was 290 fs@1028 nm, repetition frequency was 20 kHz, traveling speed was 3 mm/s, and pulse energy was 3.8 μJ, 4.5 μJ and 5.4 μJ. The experimental results showed that there are three patterns of the plasma behavior depending on the pulse energy. Plasma is generated and disappears periodically when the pulse energy is 3.8 μJ. For pulse energy 4.5 μJ, plasma exists always and the lower part of plasma vibrates little by little. When the pulse energy is 5.4 μJ, the plasma is divided, rises to a constant depth, and then the top lump of plasma disappears. These processes are repeated periodically during several tens of pulses. The threshold fluence of laser absorption by plasma was estimated comparing rising of plasma with change of the laser fluence on the optical axis. Then the relationship between rising velocity of plasma and fluence on the optical axis was investigated. Absorption energy increases as the fluence on the optical axis becomes large and the rising velocity of plasma increases. From these series of observation of plasma behavior and investigation of plasma absorption, a simple laser absorption model by the plasma was proposed. This absorption model was applied to the plasma behavior observed, and the energy absorbed in each of divided plasma was estimated. The estimated absorptance was compared with the absorptance measured in the internal processing experiment. For different pulse energy, the estimated absorptances agreed comparatively well with the experimental values, and the validity of the proposed absorption model was confirmed.

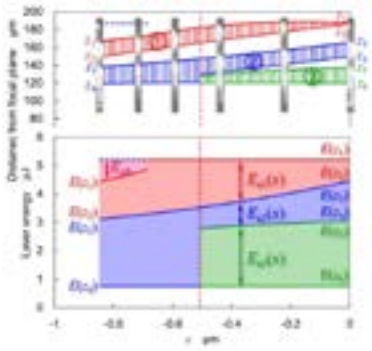

Figure1: Schematic chart of one period of plasma behavior obtained by high-speed video analysis (upper), and estimated energy which is absorbed by each plasma (lower). E(z) is laser energy at the depth z and $E_a(x)$ is energy absorbed by each plasma at the traveling distance x.

Biography

Etsuji Ohmura is a Professor of the Osaka University, Japan. His main field of research is intelligent laser processing systems, especially theoretical analysis and computer simulation to gain deeper understanding of the complicated physical phenomena in laser material processing, influence of laser optics, and nonlinear optical phenomena.

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